Introduction to Landscape Ecology

Introduction

Examples of courses offered by the Ecology Department

- **BIOL 532 Physiological Plant Ecology**
- **BIOL 506 Population Dynamics**
- **BIOL 542 Community Ecology**
- **BIOL 515 Landscape Ecology and Management**

- **BIOL 513Z Terrestrial Ecology of Plains and Prairies**
- **F&WL 510 Fisheries Science**
- **BIOL 521 Conservation Biology**

Introduction

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BIOL 521 Conservation Biology

Why do we break ecology into subdivisions to learn it? What are the pros and cons of doing this by levels of organization vs system, place, or goal?

State of Ecology in the 1970s

- **Largely based on levels of biotic organization**
  - **Cell**
  - **Organ**
  - **Individual**
  - **Population**
  - **Community**
  - **Ecosystem**
  - **Biome**
  - **Biosphere**

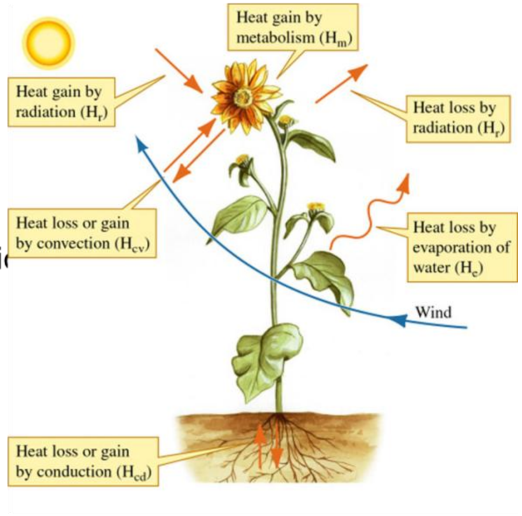
State of Ecology in the 1970s

- **Largely based on levels of biotic organization**
  - **Cell**
  - **Organ**
  - **Individual (e.g. Physiological ecology)**
  - **Population**
  - **Community**
  - **Ecosystem**
  - **Biome**
  - **biosphere**

Regulating Body Temperature

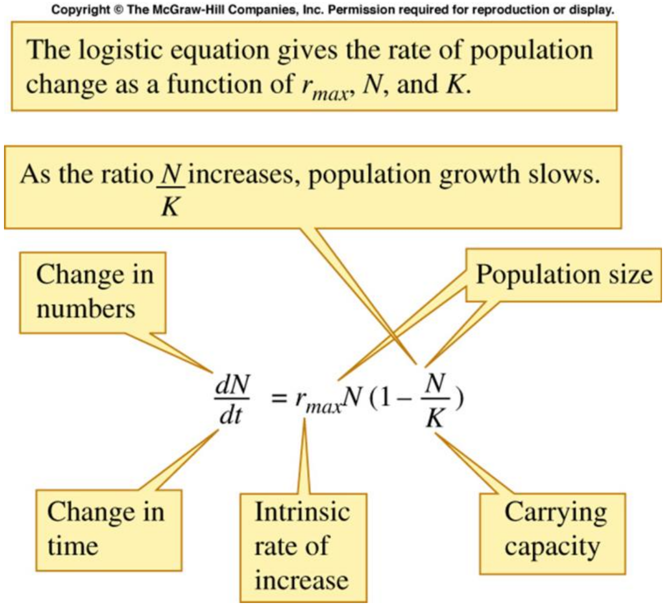
$$HS = Hm \pm Hcd \pm Hcv \pm Hr - Hc$$

- HS = Total heat stored in an organism
- Hm = gained via metabolism
- Hcd = gained / lost via conduction
- Hcv = gained / lost via convection
- Hr = gained / lost via electromag. radiati
- Hc = lost via evaporation



State of Ecology in the 1970s

- Largely based on levels of biotic organization
  - Cell
  - Organ
  - Individual
  - Population (e.g., population growth)
  - Community
  - Ecosystem
  - Biome
  - biosphere



ASSUMPTIONS OF EXPONENTIAL GROWTH EQ.

(dN/dt = rmaxN)

No immigration or emigration

Constant birth and death rates, thus resources are not limiting

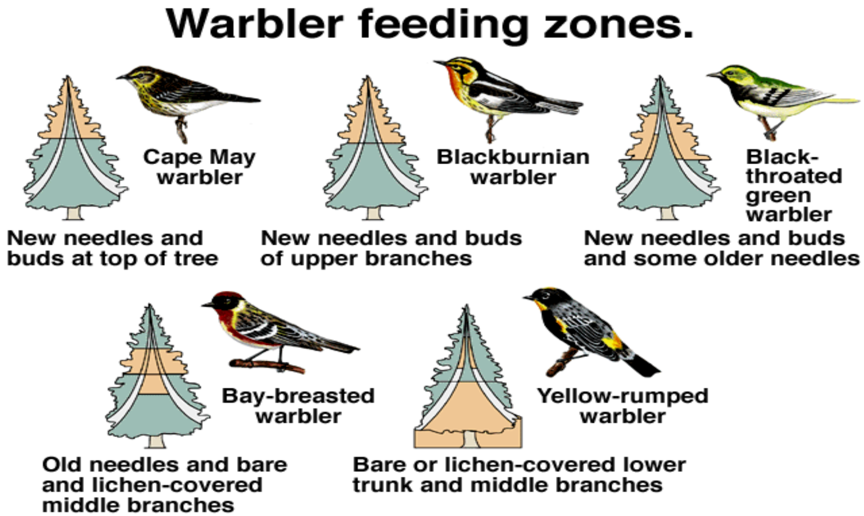
No genetic structure (all ind have same birth and death rates)

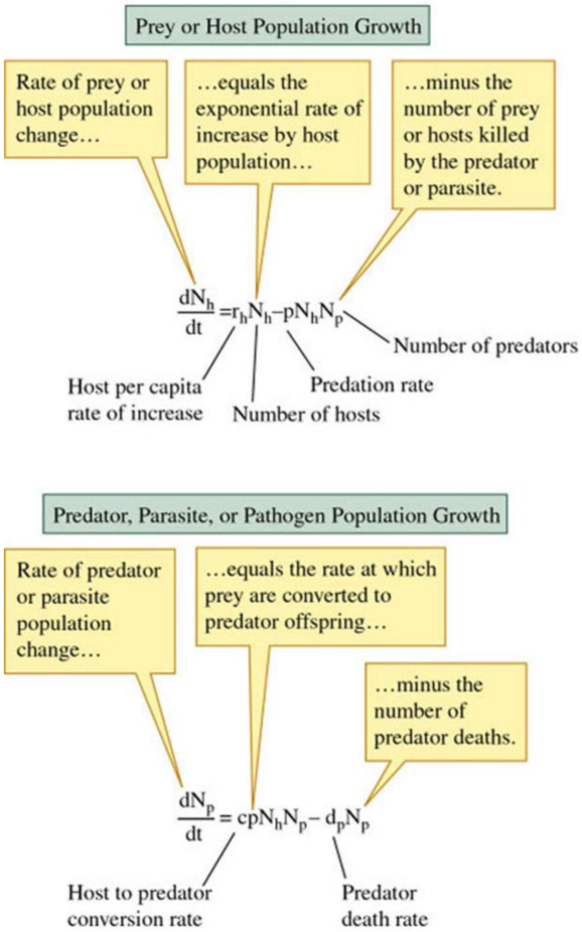
No age or size structure (all ind have same birth and death rates).

Continuous growth with not time lags.

State of Ecology in the 1970s

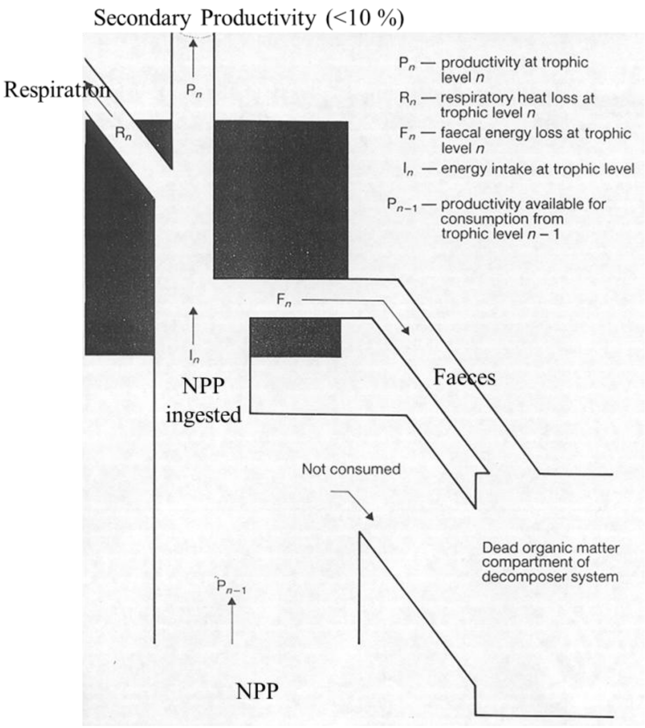
- Largely based on levels of biotic organization
  - Cell
  - Organ
  - Individual
  - Population
  - Community (e.g., competition, predation)
  - Ecosystem
  - Biome
  - biosphere

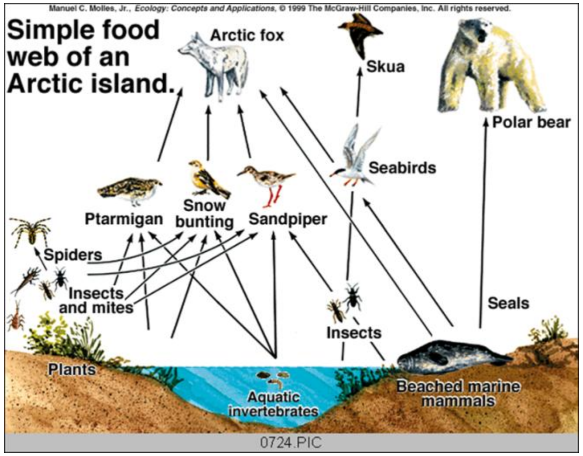




State of Ecology in the 1970s

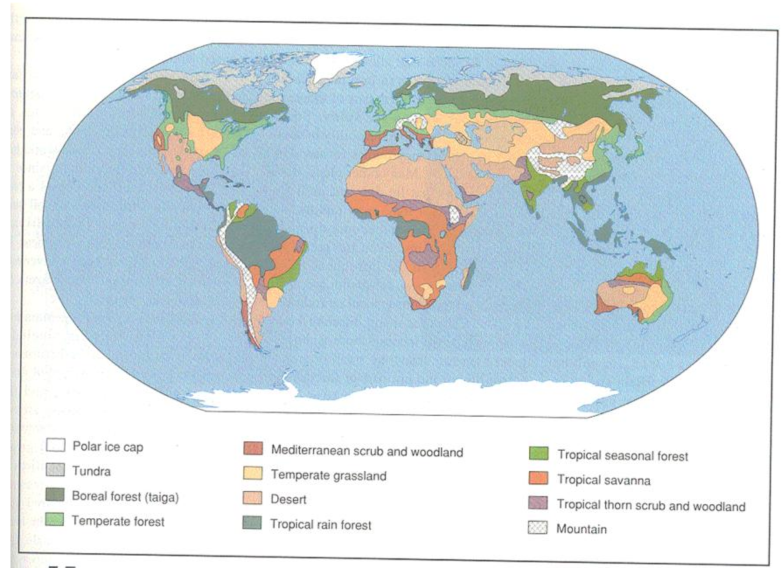
- Largely based on levels of biotic organization
  - Cell
  - Organ
  - Individual
  - Population
  - Community
  - Ecosystem (e.g. energy flow)
  - Biome
  - biosphere

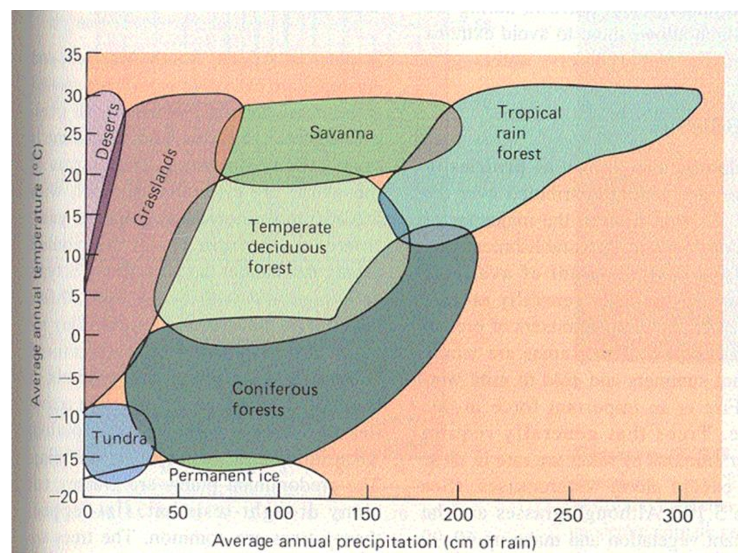




State of Ecology in the 1970s

- **Largely based on levels of biotic organization**
  - **Cell**
  - **Organ**
  - **Individual**
  - **Population**
  - **Community**
  - **Ecosystem**
  - **Biome (distribution, climate controls)**
  - **biosphere**





State of Ecology in the 1970s

- Environmental awareness and applications
  - Minimum viable population size
  - Controlling disturbances (e.g., fire, flooding)
  - Forage and wood production
  - Effects of air and water pollution

State of Ecology in the 1970s

- **Key assumptions**
  - **Environment was rather constant**
  - **Evolution was gradual and organisms were well adapted to local environment**
  - **Species distributions were determined by broad climate and by competition**
  - **Vegetation across biomes was rather homogeneous except where upset by irregular disturbance**

State of Ecology in the 1970s

- **Key assumptions**
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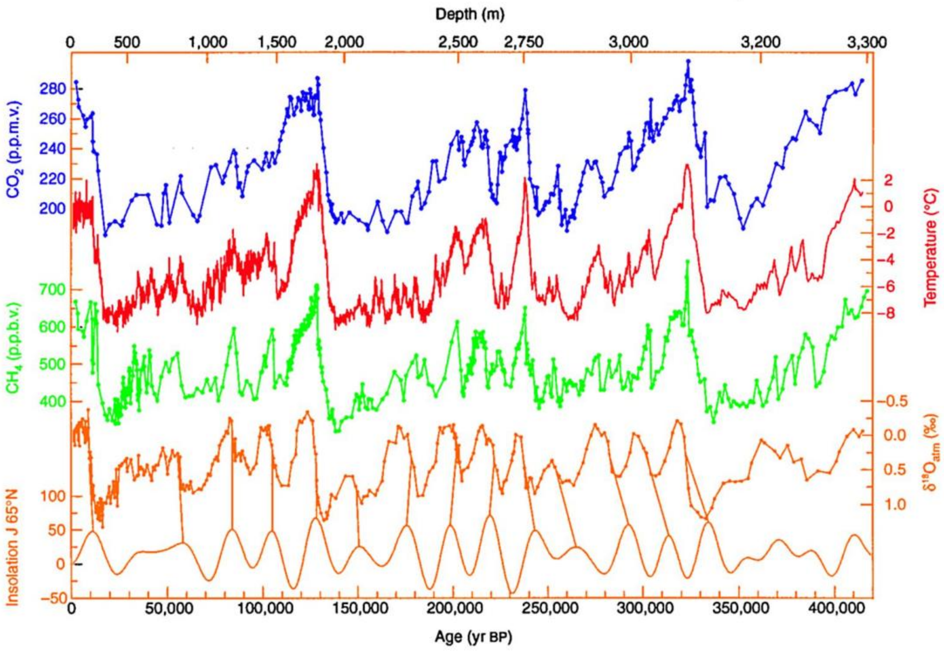
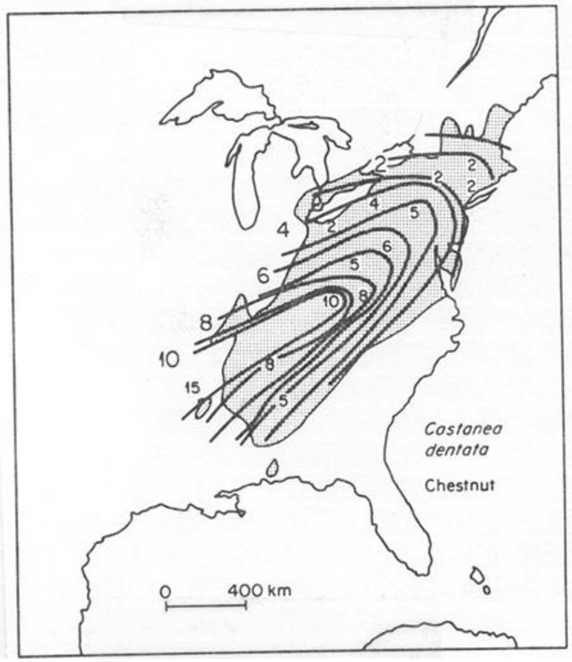
- **Spinoffs of equilibrium view**
  - **vegetation patterns seen by first European settlers had "always been there"**
  - **communities were stable in composition and patterned by climate, env gradients, competition.**
  - **humans were exogenous and cast the natural system out of balance.**
  - **conservation could best be done by setting nature reserves and leaving them alone**

State of Ecology in the 1970s

- **Puzzling problems**
  - **Climate flux and vegetation response**



Fluctuation in temperature, atmospheric gasses, and radiation over the past 400,000 years



Change in distribution of American chestnut over the 15,000 years since deglaciation.

State of Ecology in the 1970s

- **Puzzling problems**
  - **Climate flux and vegetation response**
  - **Loss of species from small forest patches**

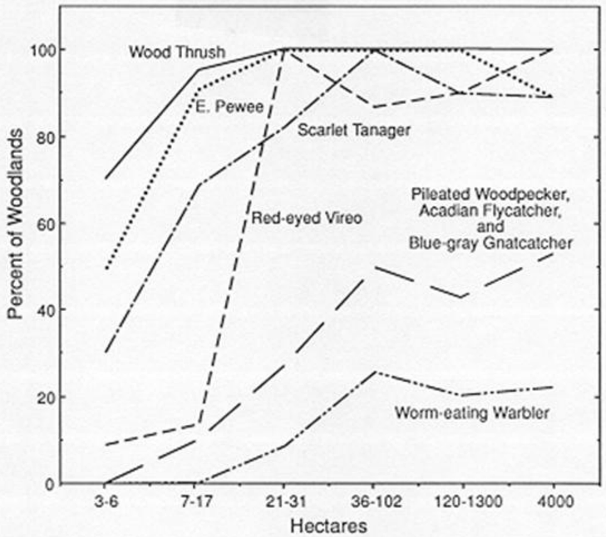


FIG. 5.1 Proportion of woodlots of each size class in which the species indicated were found (Robbins 1980).

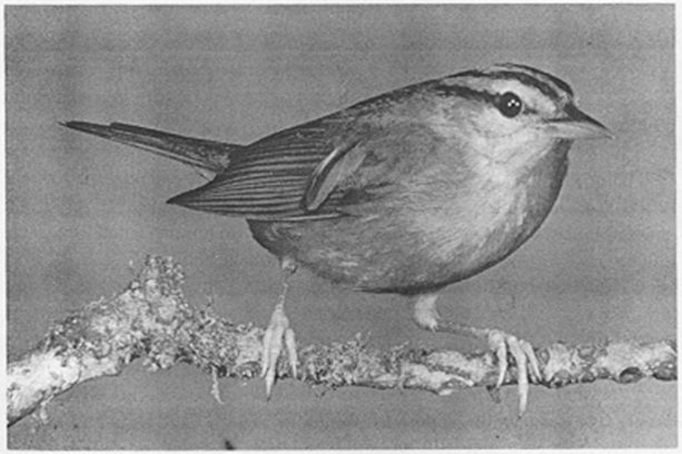


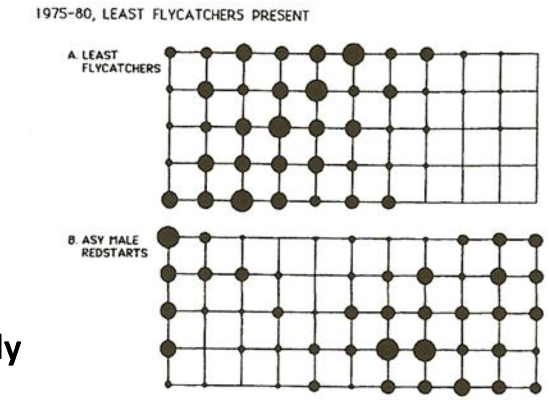
FIG. 5.2 Worm-eating warbler.

State of Ecology in the 1970s

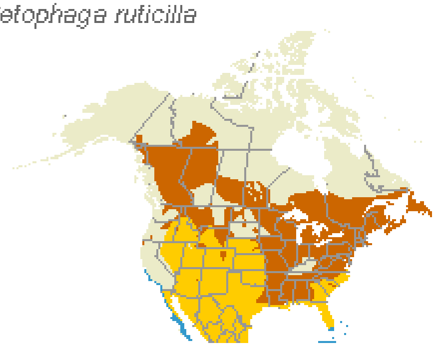
- **Puzzling problems**
  - **Climate flux and vegetation response**
  - **Loss of species from small forest patches**
  - **Natural disturbance – agent of death or balance?**

State of Ecology in the 1970s

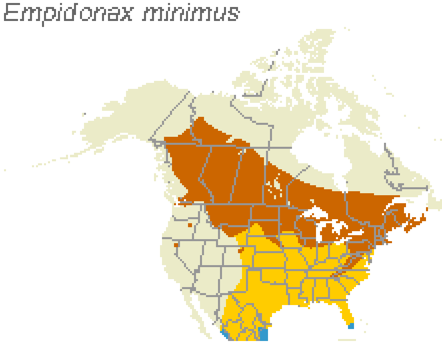
- Puzzling problems
  - Climate flux and vegetation response
  - Loss of species from small forest patches
  - Natural disturbance – agent of death or balance?
  - Biotic interactions such as competition differing locally vs regionally



American Redstart
Setophaga ruticilla



Least Flycatcher
Empidonax minimus



American Redstart (Sherry and Holmes 1988)

- **Territory location negatively influenced by presence of least flycatcher territories.**
- **Across new England, these two species are found in the same places?**

Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
  - **Populations do have immigration and emigration (e.g., Levins metapopulation model)**

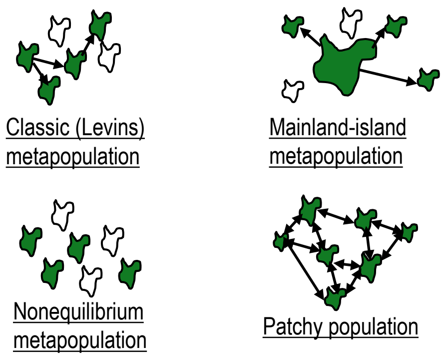
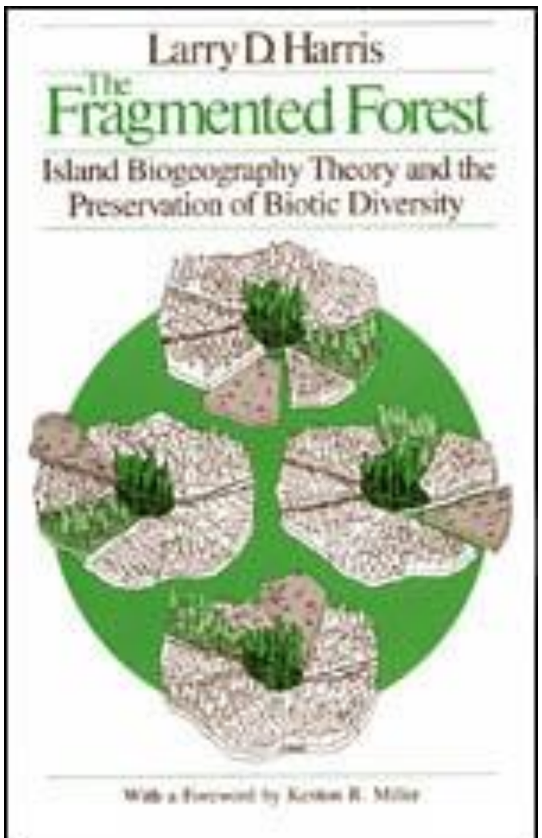


Figure 1. Types of spatially structured populations. Shaded patches are occupied; white patches are vacant. *(figure adapted from Harrison and Taylor 1997)*

Levins model. Suitable habitat is disjunct. Occupancy of a patch is a function of extinction rates in the patch relative to colonization rates. Population stability increased with dispersal among patches.

Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
  - **Populations do have immigration and emigration (e.g., Levins metapopulation model)**
  - **Adjacent patches interact (e.g., Harris's The fragmented Forest)**



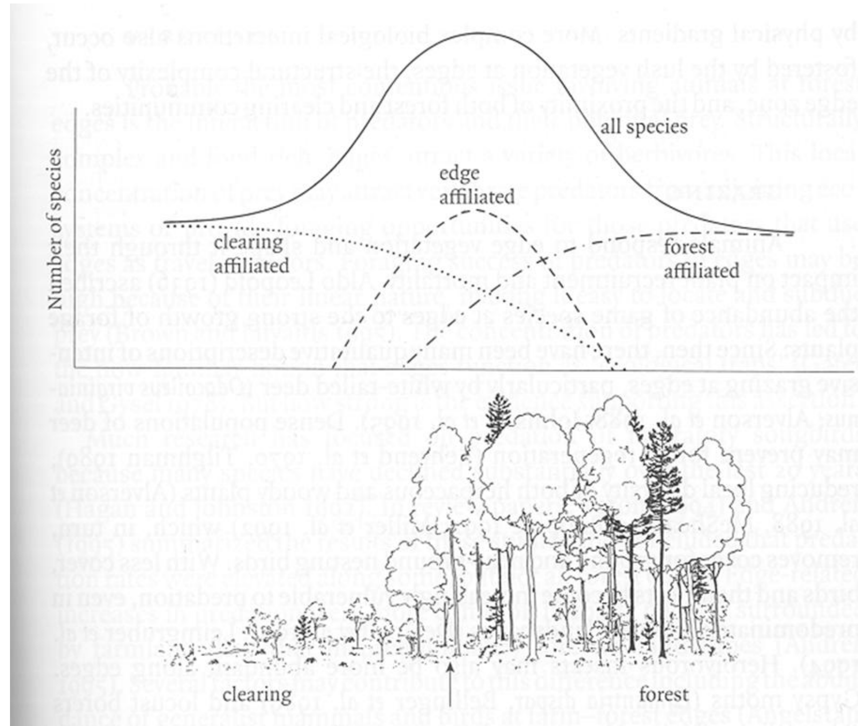


Fig. 6.4. A typical distribution of animal species at a closed forest edge. The arrow indicates the boundary of the gap-forming disturbance.

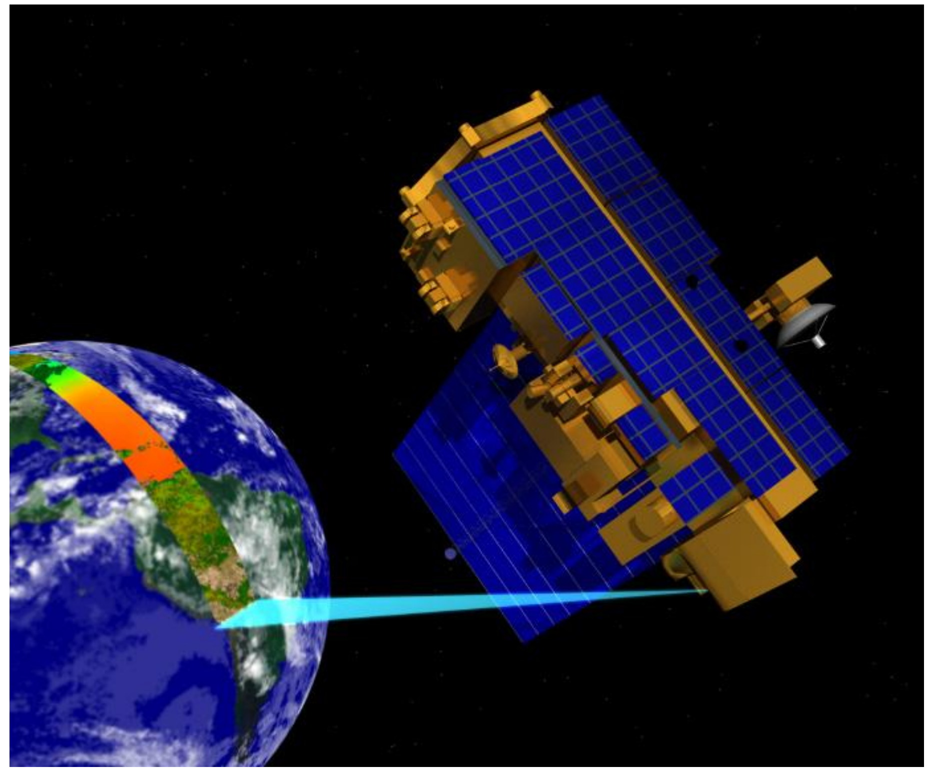
Patches interact such that along a gradient from patch edge to interior several ecological properties vary predictably including: microclimate, disturbance rates, decomposition rates, vegetation structure, vegetation composition, and animal distributions.

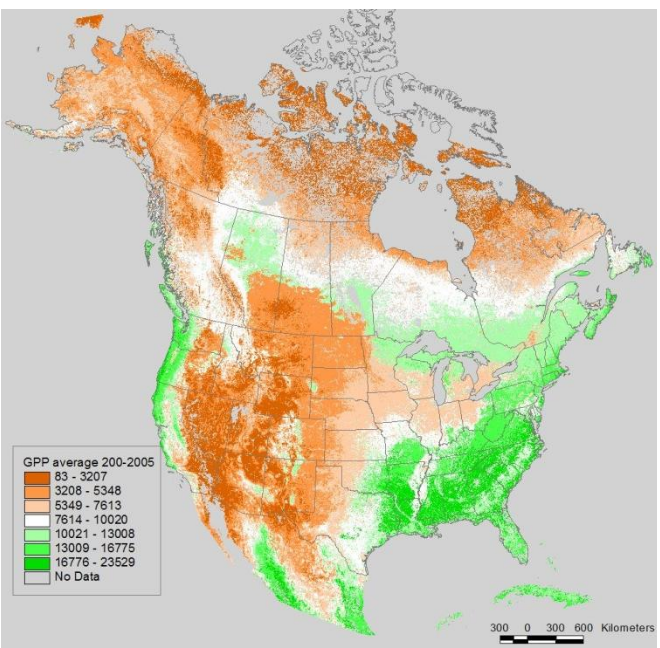
Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
- **Larger areas**
  - **New tools**
  - **Watershed, regional , continental, global areas**

New Tools: Satellite and Airborne Sensors

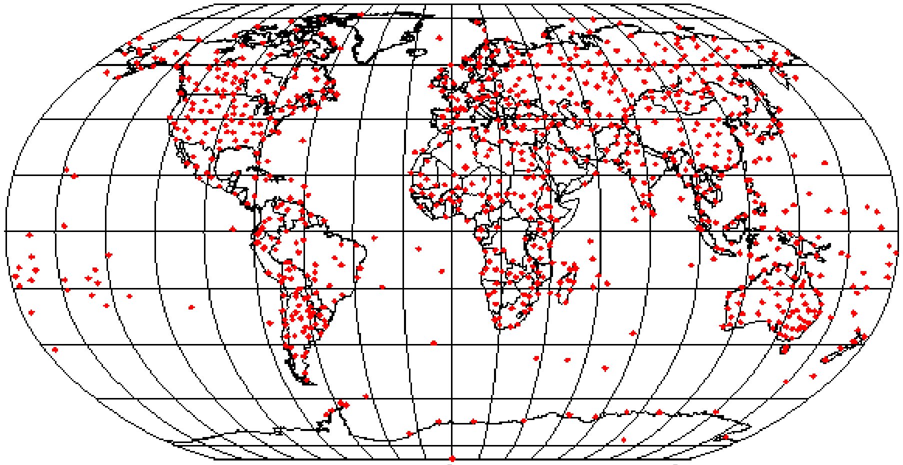
The NASA Earth Observing System is a $7.3 billion program planning satellite-based earth monitoring for 15 years, and is the heart of global change science for the United States.



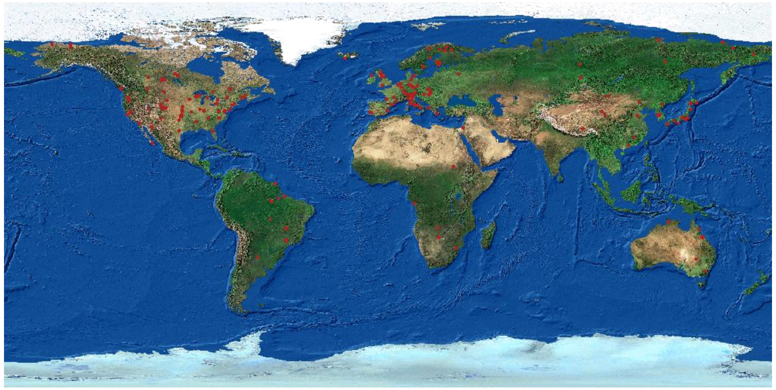


MODIS Vegetation Products	**Gross primary productivity**
	Net primary productivity
	Enhanced vegetation index
	Normalized difference vegetation index
	Leaf area index
	Land cover

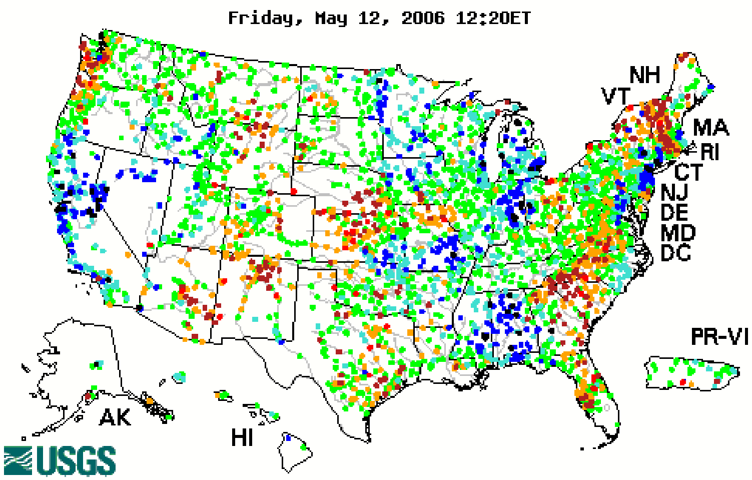
New Tools: Data Monitoring Networks



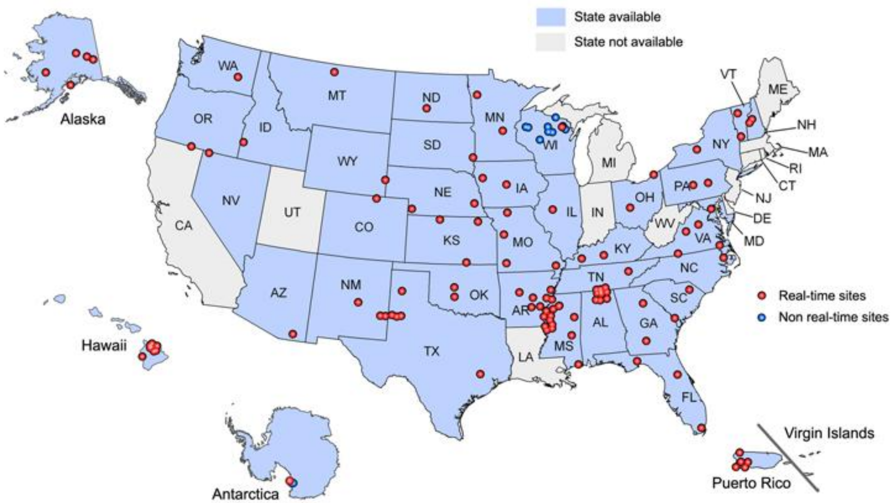
Weather network



Carbon & Energy Fluxnet

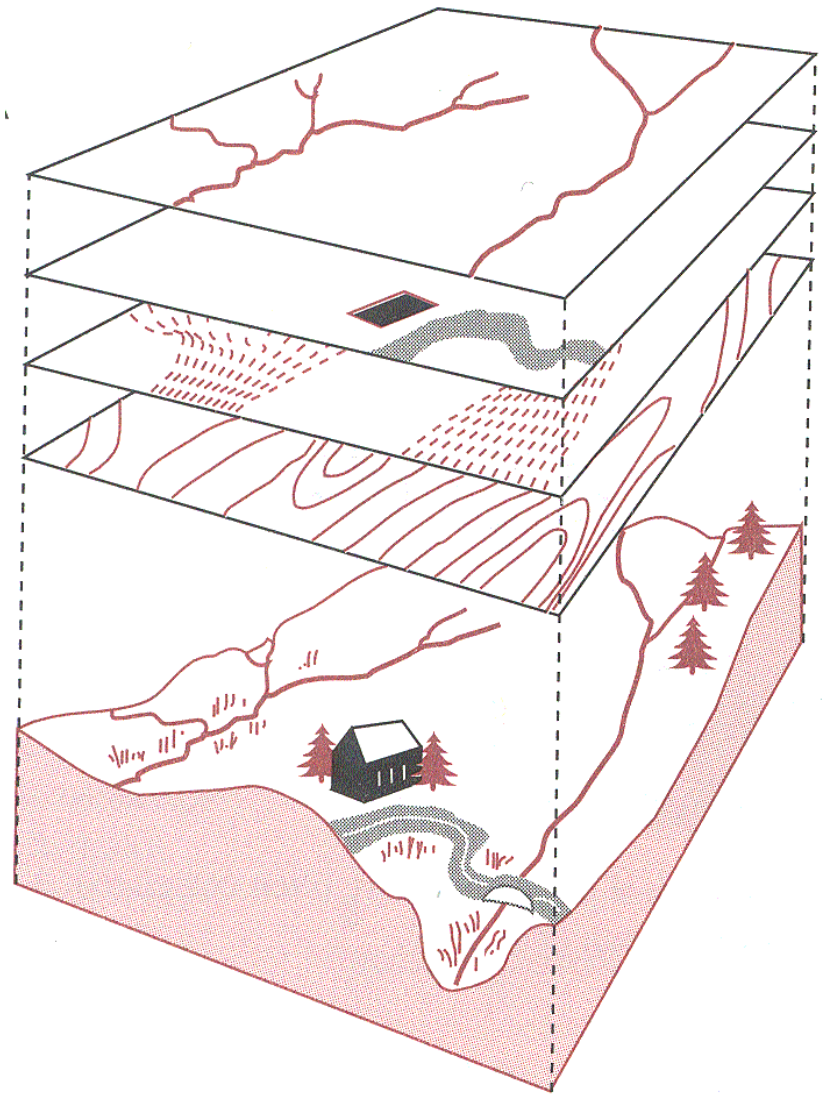


Streamflow network



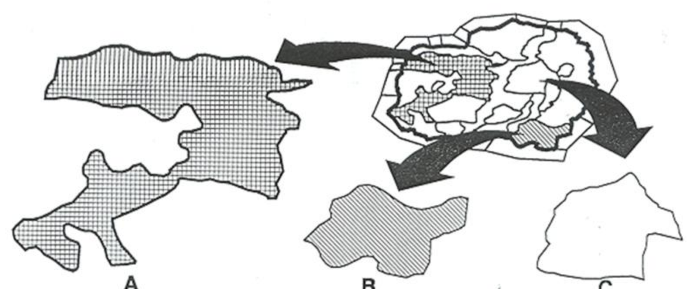
Soil moisture network

New Tools: High Speed Computers and Geographic Information Systems



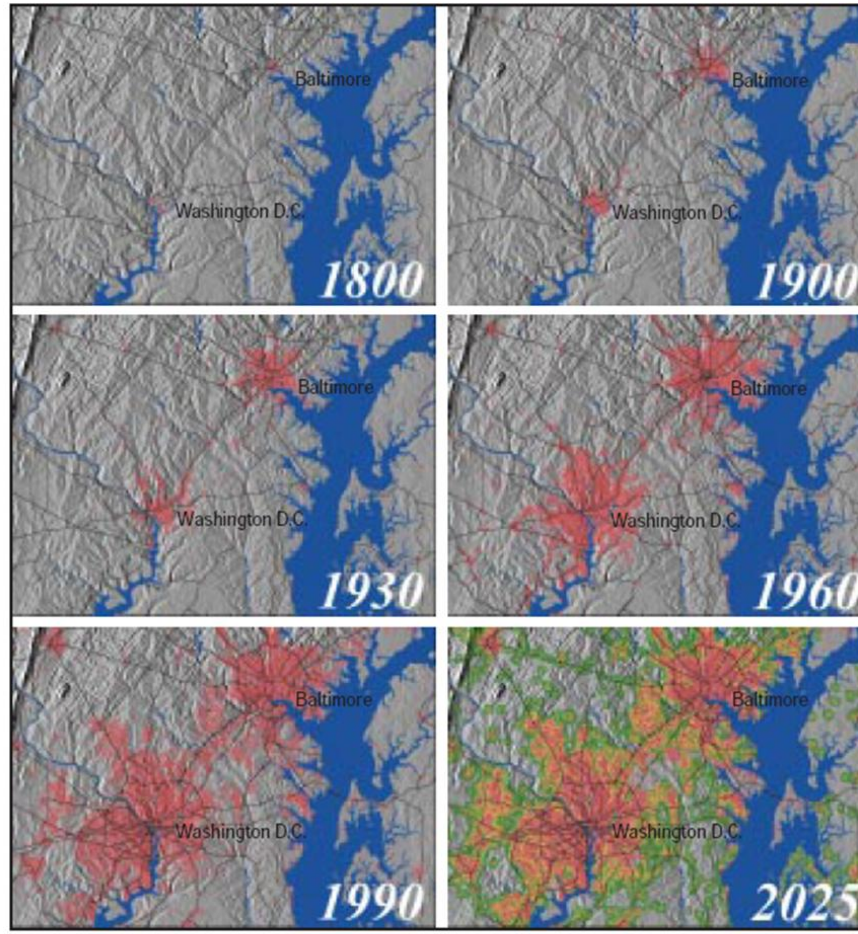
Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
- **Larger areas**
- **Quantitative methods**
  - **Metrics for quantifying spatial pattern: composition and configuration**
  - **Ways to measure movement**
    - Percolation theory
    - Circuit theory
    - And application to how to maintain connectivity among wildlands
  - **Spatial simulation models**
    - Protect alternative futures across large areas.



	A	B	C
LID	NCVEG	NCVEG	NCVEG
PID	104	400	200
TYPE	MLS	COS	MGF
AREA	51.33	16.83	18.59
LSIM	48.80	7.62	8.41
PERIM	6230	1922	1907
EDGECON	16.96	42.02	80.05
SHAPE	2.45	1.32	1.25
FRACT	1.33	1.26	1.25
CORE	8.46	2.35	4.62
NCORE	2	1	1
CAI	16.48	13.94	24.87
NEAR*	25.00	155.08	216.91
PROXIM*	200.34	2.38	0

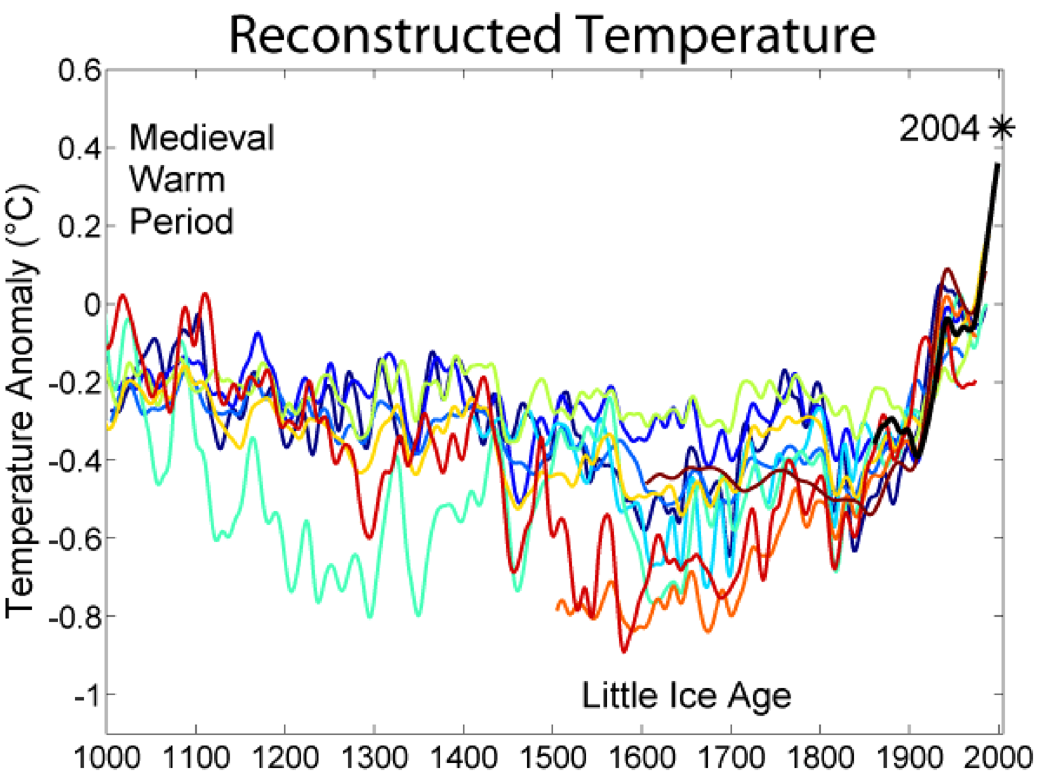
Figure 4. Example of FRAGSTATS patch indices for 3 sample patches drawn from a sample landscape. See text and Appendix for a description and definition of each metric. Indices with a '*' were computed using the raster version of FRAGSTATS.



This series of maps shows more than 200 years of urban growth in and around the Washington, D.C. area. The background in each map is a shaded-relief image. The red areas represent urban extent for each time period and the blue is Chesapeake Bay. Projections for 2025, made with a land use change model, show likely areas of new urban growth in yellow (high probability) and in greens (light green is moderate probability; dark green is low probability).

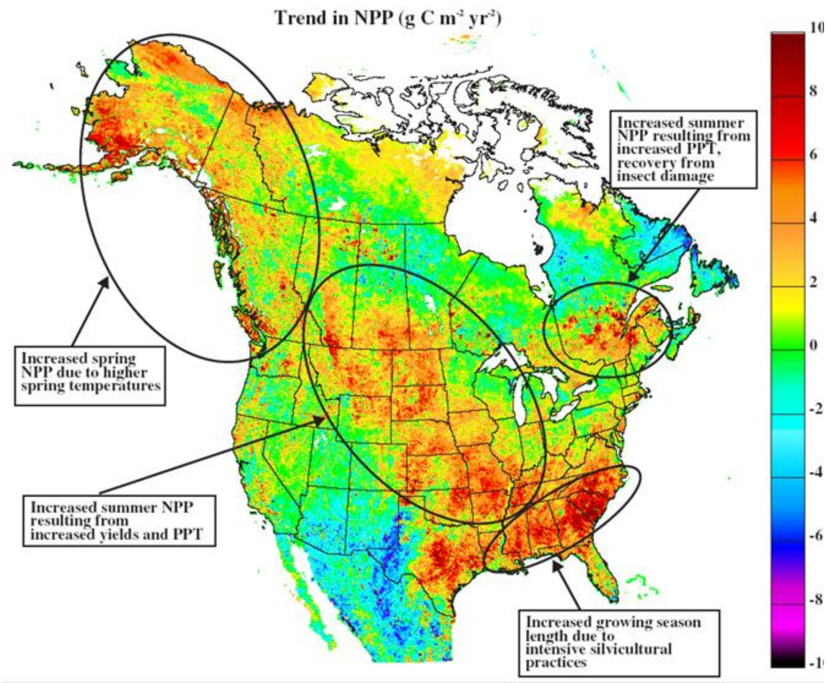
Emergence of Elements of Landscape Ecology in the 1980s

- Interactions across space
- Larger areas
- Quantitative methods
- Longer time periods
  - Paleoecology to go way back, long-term field measurements for past decades to century, simulation to project into the future
  - Application -how different are conditions now than at various times in the past? How much of the variation we see is natural vs human caused?

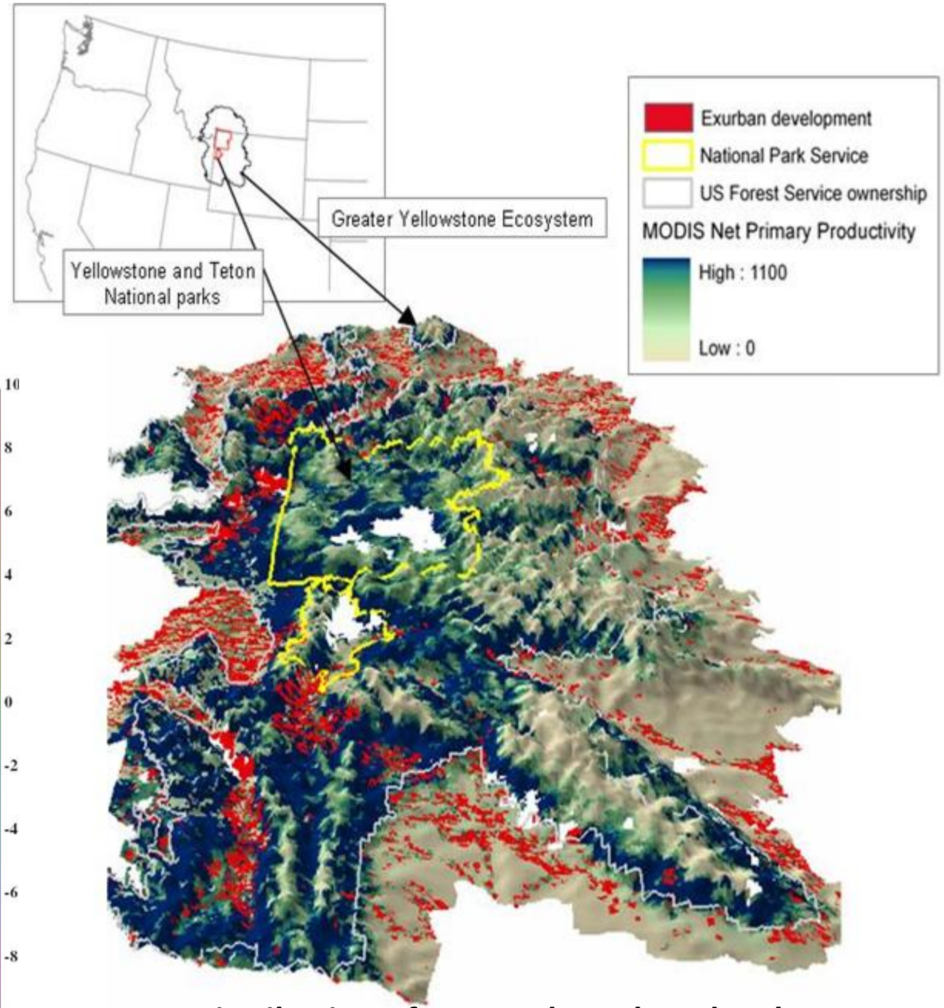


Emergence of Elements of Landscape Ecology in the 1980s

- Interactions across space
- Larger areas
- Quantitative methods
- Longer time periods
- Place matters
  - Climate, soils, topography, biota differ from place to place.
  - Ecological processes and biodiversity vary accordingly.



Percentage increase in NPP (1982–1998)



Distribution of NPP and exurban development across the Greater Yellowstone Ecosystem.

Emergence of Elements of Landscape Ecology in the 1980s

- **Interactions across space**
- **Larger areas**
- **Quantitative methods**
- **Longer time periods**
- **Place matters**
- **Scale**
  - **If a landscape is defined by interactions among its pieces, does it matter how big the area is?**
  - **What is the right scale to address a particular problem?**
  - **Hierarch theory**
  - **Application - how big did protected areas need to be.**

<u>Levels of Organization</u>

individual

population

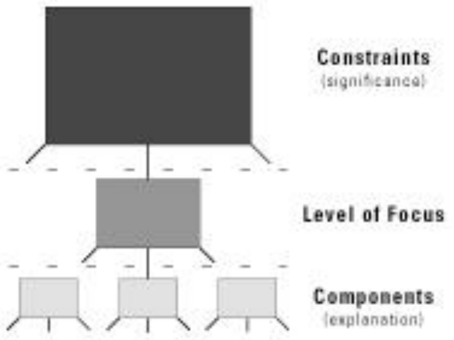
community

ecosystem

landscape

biome

biosphere

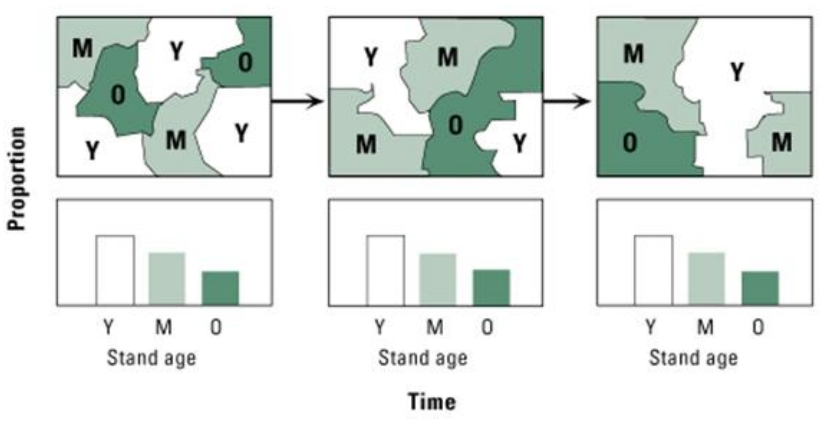


A hierarchy is defined as a system of interconnections wherein the higher levels constrain the lower levels to various degrees, depending on the time constraints of the behavior.

Upper levels constrain the focal level and provide significance. Lower levels provide details required to explain response of focal levels.

Emergence of Elements of Landscape Ecology in the 1980s

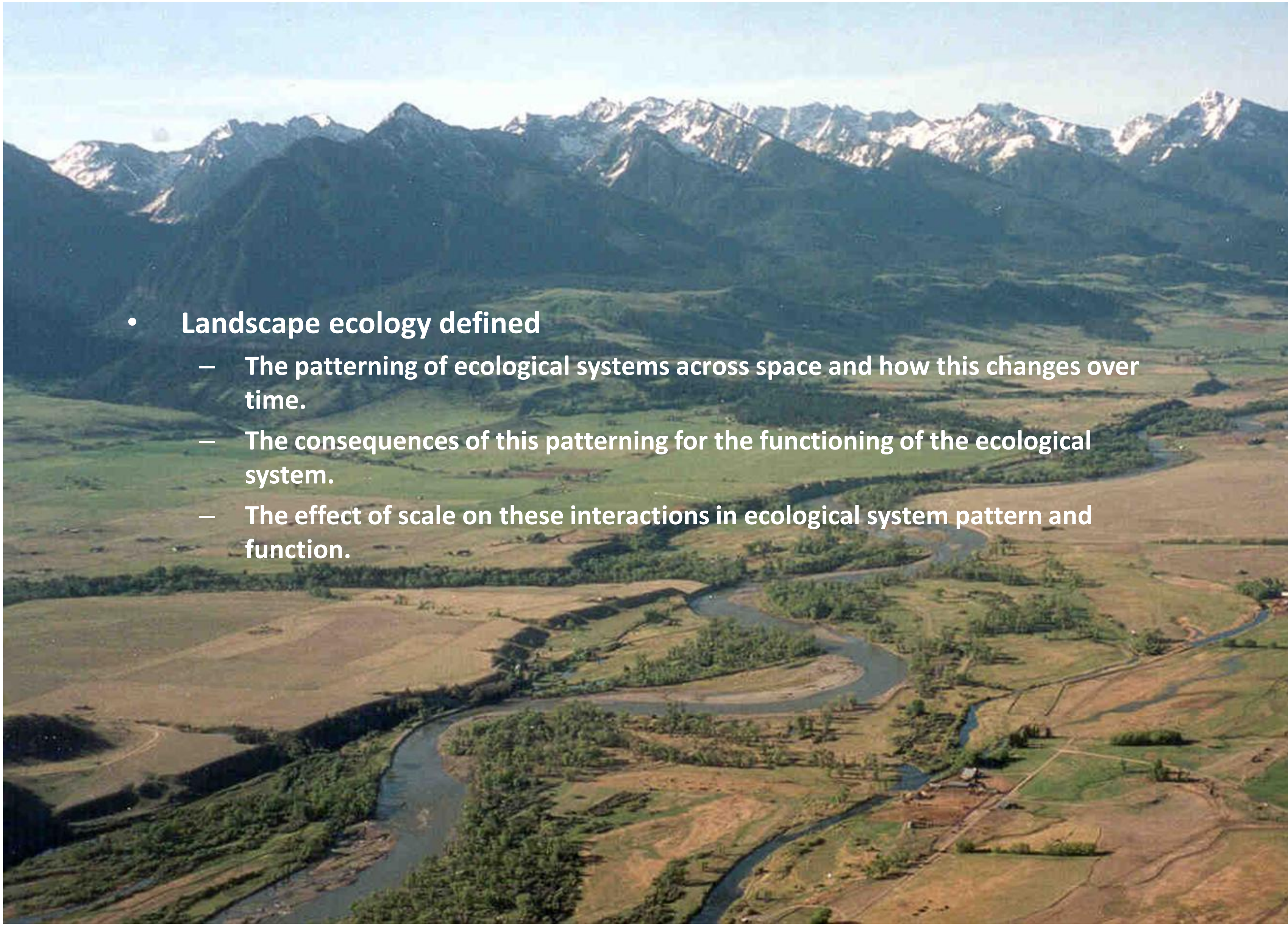
- Interactions across space
- Larger areas
- Quantitative methods
- Longer time periods
- Place matters
- Scale
- Equilibrium vs Disequilibrium
  - Perturbation at one scale may be equilibrium at a larger scale.
  - Notion of natural range of variation and application as a guide for management



Shifting Steady-State Mosaic - A landscape where the characteristics of individual patches are out of phase but the collective behavior of patches displays equilibrium.

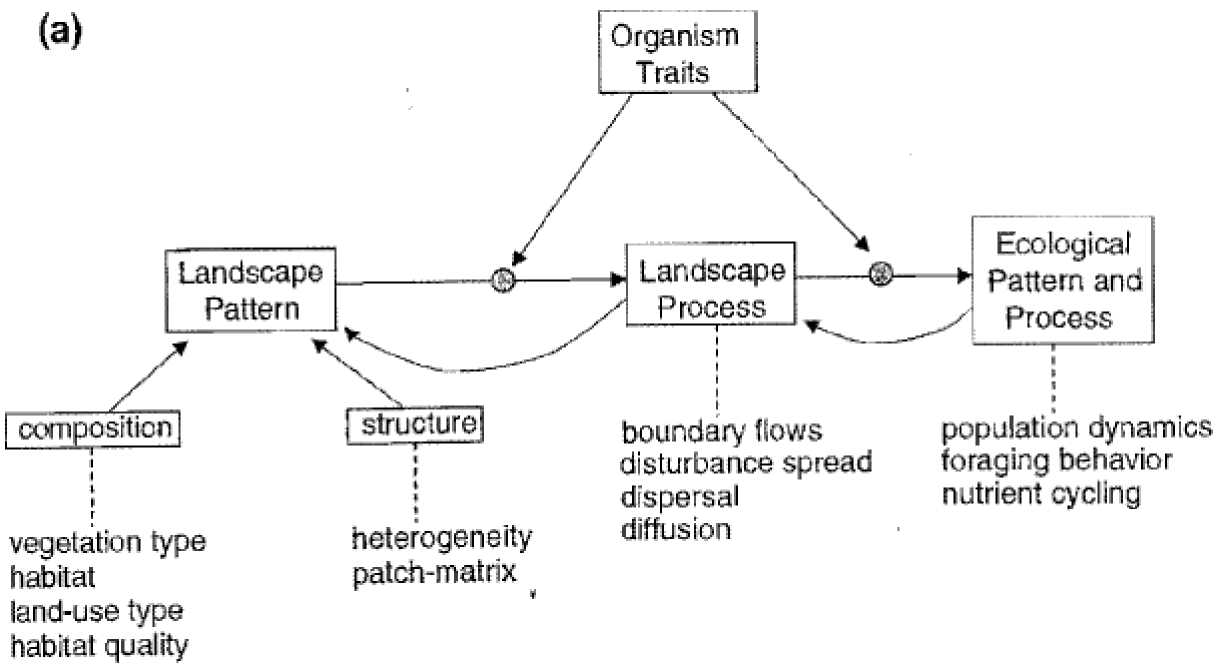
Current Understanding of Landscape Ecology

Current Understanding of Landscape Ecology



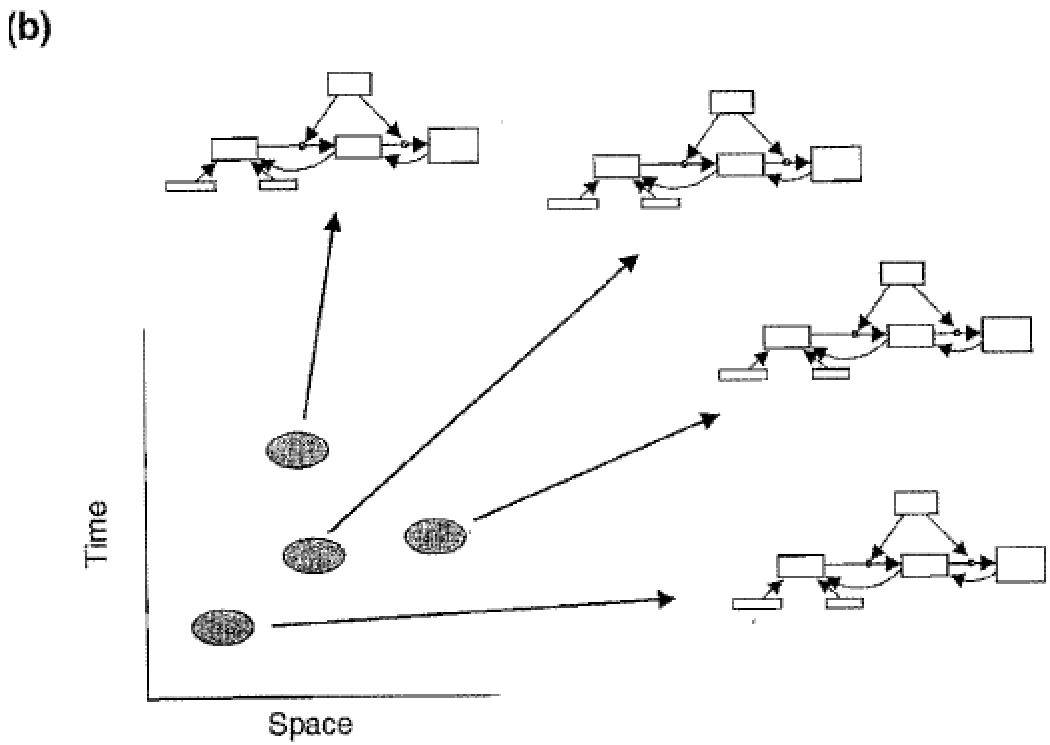
- Landscape ecology defined
  - The patterning of ecological systems across space and how this changes over time.
  - The consequences of this patterning for the functioning of the ecological system.
  - The effect of scale on these interactions in ecological system pattern and function.

Current Understanding of Landscape Ecology



Elements of a framework for thinking about landscape effects on ecological systems (Wiens 2002).

Current Understanding of Landscape Ecology



Because all of the components of the web of spatial interactions shown in (a) may change with changes in scale, the resulting ecological patterns and processes that we study and attempt to manage will probably differ among different space-time scaling domains (shaded ellipses). (Wiens 2002).

Current Understanding of Landscape Ecology

- **Wiens 5 foundational concepts in landscape ecology**
  - **Landscape Elements Differ in Quality**
  - **Patch Boundaries Influence Ecological Dynamics Both Within and Among Patches**
  - **Patch Context Is Important**
  - **Connectivity Is a Key Feature of Landscape Structure**
  - **Spatial Patterns and Processes Are Scale-Dependent**

Current Understanding of Landscape Ecology

- Landscape ecology unique in:
  - Focus on importance of spatial configuration for ecological processes;
  - Focus on spatial extents that are much larger than those traditionally studied in ecology.

- The main goal:
  - Understand how nature works.
  - Use knowledge to manage landscapes.

Current Understanding of Landscape Ecology

- **Present Focus of Landscape Ecology (Turner 2005)**
  - **Conditions under which spatial pattern must be considered: when does space matter?**
  - **Understanding spatial dynamics: the linkage of space and time**
  - **Nonlinearities and thresholds: expecting the unexpected**
  - **Planning, managing, and restoring landscapes**

Issues Now at the Forefront

- The continent or globe as a landscape.
  - NEON aimed at continental scale ecology
  - Global conservation strategy
  - Global carbon budgeting

- Accurate hindcasting and forecasting of spatial heterogeneous ecological systems

- Humans and ecosystems as coupled socio ecological systems
  - with feedbacks including human impacts on ecological systems, alteration of ecosystem services, effects on human well being

- Management of ecological and human systems under climate change